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SEASONAL AND VEGETATIONAL VARIATION IN ALBEDO MEASURED DURING CERES GROUND-VALIDATION PILOT STUDY

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INTRODUCTION

The Clouds and the Earth's Radiant Energy System (CERES) satellite is scheduled for launch in the Fall of 1997 aboard the Tropical Rainfall Measuring Mission (TRMM) platform (Wielicki et al. 1996). A surface measurement pilot study has been initiated in a 37-km region near Richmond, VA, for comparison with the CERES surface flux retrievals (see Figure 1). Two-minute averaged upwelling and downwelling surface fluxes over a mostly deciduous forest have been recorded daily for the past two years, and show a broadband, shortwave daily albedo increase during the summer months. Evidence is presented that indicates vegetational changes in the forest as the overriding mechanism for this change. Upwelling flux measured over the entire region by helicopter-mounted instrumentation has been processed for four solar seasons. Future plans include the installation of four more albedo surface sites over various types of vegetation throughout the region.

APPARATUS

The instrumentation, procedures, and sample output produc are provided elsewhere at this conference (Moats et al. 1996, Wheeler et al. 1996). Briefly, the surface instrumentation consists of five uplooking and downlooking wide-field-of-view radiometers: broadband longwave (5-50 µm), broadband shortwave (0.3-3 µm and 0.4-1.1 µm), narrowband shortwave (.51-.61 µm), and photosynthetically-active radiation (PAR, 0.4-0.7 µm). The downlooking radiometers are mounted on a GTE cellular telephone tower 140 feet above the forest canopy, while the uplooking instruments are located above the shadowing effects of the forest on a smaller, 70-foot tower. An all-sky cloud camera enables the identification of cloud type throughout each day, and an additional camera mounted above the forest records seasonal vegetation changes of the canopy. The daily-average broadband albedo is computed as the ratio of the sum of the upwelling shortwave flux for the entire day divided by the sum of the downwelling shortwave flux for the entire day. Only daytime data was used for the computation in an effort to eliminate the impact of the negative night-time fluxes indicated by the instruments. The results for 1995 are shown in Figure 2.

Similar downlooking instrumentation is mounted below a UH-1 helicopter (Wheeler et al. 1996) for collection of upwelling flux over a 37-kilometer region surrounding the surface site on clear-sky days during each of the four seasons. Use of this data in conjunction with surface uplooking data obtained at the site during the same time period enables the computation of the albedo over the entire region, and will provide a better comparison with satellite data than measurements obtained at a single location.

DISCUSSION

Figure 2 indicates a steady albedo marred by occasional precipitation at the beginning of the year. An increasing trend began to occur on about day 95, and reached a peak on about

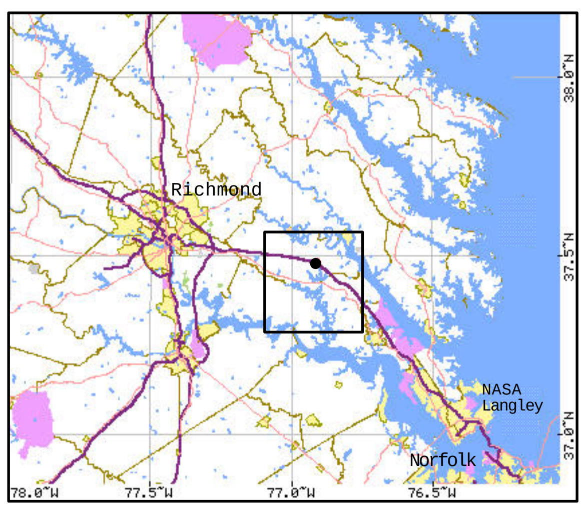

Figure 1 -- 37 km region of helicopter nadir albedo flights. Dot inside of box denotes location of surface measurement.

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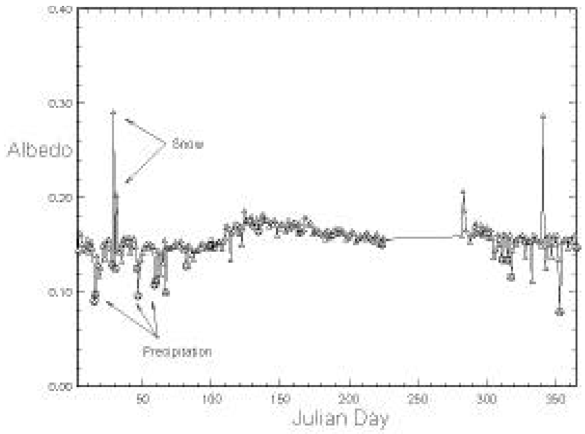

Figure 2 -- Daily averaged broadband shortwave surface albedo over forest in Southeast Virginia, 1995.

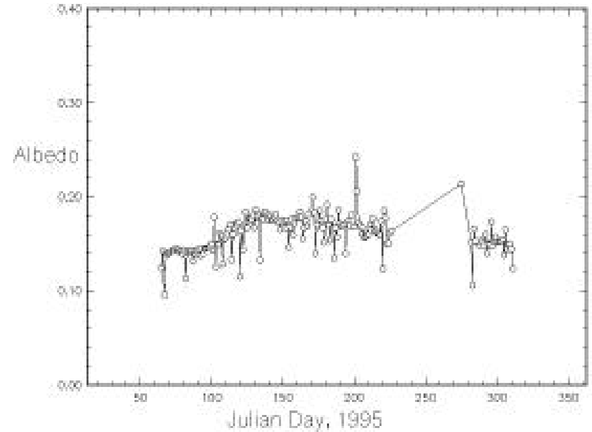

Figure 3 -- Instantaneous surface albedo over forest site for a solar zenith angle of 49 degrees.

day 130. Thereafter, the albedo decreased slowly until the tower became inoperative on day 225. A slight increase in albedo occurred while the tower was off line, but it tapered off to values nearly the same as those found at the beginning of the year. Mechanisms that may be causing this seasonal variation in the daily albedo include maximum solar elevation, seasonal cloud variations, changes in vegetation, and soil moisture. All of these items will be discussed here except for the soil moisture (soil moisture measurements were not available at the tower in 1995.)

Maximum solar elevation angle. The albedo over the forest is not continuous throughout any given day. It is generally the greatest at the beginning and end of the day, when low solar elevations lead to increased specular reflection. Hence, one might expect the albedo to decrease in the summer months, when a greater portion of the day is influenced by high solar elevations. This is contrary to the trend that seen in Figure 2, so it may be inferred that the daily maximum solar elevation angle is not the predominant mechanism affecting the seasonal change in the forest albedo.

Further evidence in support of this hypothesis may be observed by inspection of the broadband instantaneous albedo measured at constant solar elevation, shown in Figure 3. Each data point in Figure 3 represents the 2-minute averaged albedo when the solar zenith angle decreases to 49 degrees for the first time of the day. This processing of the data at a constant solar zenith angle eliminates any impact of maximum solar elevation found in daily-averaged albedos. However, the short temporal scale of this plot makes it more susceptible to noise induced by inhomogeneous clouds. The annual trend in instantaneous albedo in Figure 3 is similar to the trend of the daily albedo in Figure 2, indicating that seasonal albedo changes still occur at a constant solar illumination angle.

Seasonal cloud variation. The instantaneous albedo at the projected CERES overpass time for various cloud types observed by the all-sky camera is shown in Figure 4. It is not apparent that any particular cloud type is favored during any time of the year, and therefore a “cloudy season” or “sunny season” should not be responsible for the seasonal albedo change. Inspection of the figure also reveals that the seasonal variation in albedo is present for clear-sky days throughout the year, further indicating that variation in cloud type is not the culprit.

Seasonal changes in vegetation. Vegetation changes were video taped with a camera placed well above the forest canopy. The appearance of the canopy was divided subjectively into 5 categories -- bare, green, brown, orange, and snow. The results of this tedious task are shown in Figure 5. The appearance of the forest remained constant until day 94, at which point it started to “green up” rather rapidly. The metamorphosis was complete on day 121, and the forest remained completely green until day 286. As Autumn ensued, the percentage of green in the forest dropped to the previous winter value of 5 percent on day 334.

The vegetation changes of the forest in the 2nd quarter of the year appear to be in phase with the seasonal changes of the albedo shown in Figure 2. That is, the albedo increases as the deciduous trees in the forest renew their leaves. The albedo decreased some throughout the summer when there was no change in the forest, but 1995 was a hot and dry summer in Southeast Virginia, and this may have had an impact on the albedo. It should be noted that the percentage of bare forest was greater at the end of 1995 than at the beginning (at the expense of the brown forest.) This may be why the daily albedo is slightly higher at year’s end. (Fig. 2).

FUTURE VALIDATION PLANS

Instrumentation has been procured for the installation of four portable measurement sites throughout this region. Each site will contain broadband shortwave, narrowband shortwave, and eventually PAR radiometers. Downlooking instrumentation will be mounted on a 20-foot guyed pole over various vegetation types throughout the region, with the accompanying uplookers on 6-foot tripods nearby. (This instrumentation

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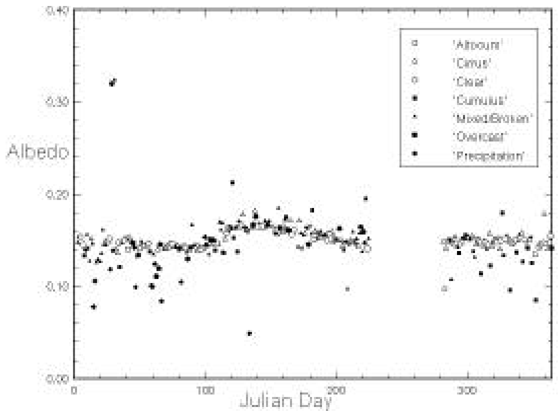

Figure 4 -- Instantaneous surface albedo over forest site at 1554 GMT, 1995.

was used during the Atmospheric Research Measurement (ARM) Enhanced Shortwave Experiment (ARESE). A more complete description may be found on the internet at http://wind.larc.nasa.gov:8001).The albedo measured at these sites may then be extrapolated to the entire region with land-type weighting functions obtained from Landsat imagery, enabling comparisons with helicopter measurements and CERES surface retrievals.

CONCLUSION

Daily surface albedo over a mostly deciduous forested site in Southeast Virginia has been monitored for the past two years as part of a CERES validation pilot study. The data indicate that vegetation changes are the primary cause of the seasonal variation in the albedo. Helicopter-mounted flux instrumentation has been used to measure the albedo in a 37-km region surrounding the surface site for four solar seasons. Future plans include a network of albedo instrumentation throughout this region. Both the helicopter measurements and the surface measurements will be used to validate CERES surface flux retrieval algorithms.

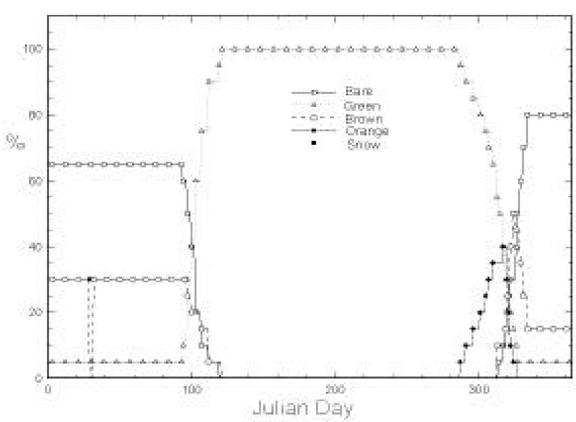

Figure 5 -- Visual appearance of the forest at the surface measurement site.

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